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Selection of Open Innovation Method in the Automotive Industry Using Adaptive Network-Based Fuzzy Inference System

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Abstract

Previously, companies relied only on internal intellectual resources and tried to develop and commercialize ideas within the organization. The open innovation approach leads companies to make more use of external technologies in their activities and allows other companies to use their innovations. Open innovation methods have a high diversity, but each economic enterprise should use one or more methods compatible with the company's situation according to its conditions. In the current research, an Adaptive Network-based Fuzzy Inference System (ANFIS) has been used as one of the methods of artificial intelligence and MATLAB software to choose the appropriate method of open innovation in the automotive industry. For this purpose, two inputs under the title of company's technical knowledge level and the complexity of parts technology and nine possible modes for the output, including all kinds of open innovation methods, are considered in the fuzzy inference system so that by using the existing rules, a technique suitable to the company's conditions can be extracted. In this research, 50% were considered training data for model design, and 50% were considered test data for model evaluation. The designed model selected open innovation methods with 90% accuracy. Therefore, the presented model is a suitable tool for choosing the open innovation method for the automotive industry.

Keywords: Open innovation, Automotive industry, Open innovation methods, Adaptive network-based fuzzy inference system.

1 | Introduction

Maintaining a position in the competitive business environment is the primary concern of industries, which is not possible for companies alone. Many large companies, which were among the leaders of the automobile

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industry for many years, saw their position at risk in the face of the rapid developments in the market and turned to cooperation with their competitors to maintain their competitive position. Collaborations between General Motors and Toyota to build joint cars clearly exemplify this [1]. Also, Toyota's partnership with Citroën of France is another example of these collaborations [2].

In trying to take advantage of external knowledge, they have increasingly directed their innovation management towards open innovation networks to integrate external partners and customers. The purpose of open innovation is to open the company's borders, to flow knowledge from outside the organization, and to create opportunities for cooperation with partners and customers in line with innovation processes. Open innovation can help companies to achieve and maintain a competitive advantage [3]. Since closed innovation only deals with internal knowledge sources and spends a lot of money to acquire technology, today, an open innovation approach is proposed to reduce costs [4].

Rapid changes in the field of technology, increasing research and development costs, competition in providing new products and services, and reducing the life cycle of products and technologies have led to an increase in the need for companies to interact with the environment and external stakeholders through the exchange of innovative ideas [5]. Open innovation is managing the organization's incoming and outgoing knowledge flows. The main issue is that an essential part of the knowledge that can keep a business innovative is at the disposal of the organization's users, customers, and other external sources, which can benefit from the open innovation approach [6].

The advantages of technology in increasing the accuracy and speed of affairs, reducing costs, and customer satisfaction have made companies use information systems. In fact, in today's business environment, technology is viewed as a competitive resource [4]. Also, the results of the studies show that innovative projects primarily based on external development have shorter development times than similar projects that rely entirely on internal research and development. They need less investment [7].

Despite cooperation with foreign companies such as Renault and Peugeot of France, Nissan of Japan, Changan of China, Kia Motors of South Korea, and other companies, Iran's automobile industry has not been successful in producing products and acquiring technologies in the field of the automobile industry [2]. Because appropriate investments have not been made in the innovation sector, there is no suitable platform for exploiting new ideas. This has caused them to not have the necessary competitive position due to reduced productivity, reduced product quality, and customer dissatisfaction to participate in global supplies. In the automotive industry, due to the wide variety of cars and production parts, companies compete with each other to obtain the market by promoting products that meet the needs of customers [8].

Technology is the driving force of development in today's era, and the main foundation of technology is innovation. In the past, it relied on closed innovation and internal company resources, but now, innovation is emphasized again. Since the position of each company depends on many variables and the range of open innovation methods is very large, it is necessary to define a framework for optimal use to increase competitiveness in a rapidly changing technological world. Therefore, according to the above-mentioned topics, this research aims to provide a model for choosing the open innovation method using the Adaptive Network-Based Fuzzy Inference System (ANFIS) in the automotive industry to increase the level of technology acquisition.

The structure of this article is such that after the introduction, in Section 2, there is a review of the literature and the background of the research. In Section 3, the research methodology is described. In Section 4, the research findings are presented in the form of a proposed model, and at the end, conclusions and suggestions are discussed.

2|Literature Review

2.1|Open Innovation

The open innovation approach, used to develop technology and new ideas outside the organization, is proposed as a solution against the reduction of product life, accelerated technology cycles, and increased global competition [4]. To widely identify innovation and new ideas outside the organization, it is necessary to analyze a wide range of innovation data from heterogeneous sources [9]. Innovation is a mental process that leads to creating a new phenomenon. This new phenomenon may be a material product, a new service, or a new technique. Creativity and innovation are the analysis or combination of several concepts and the creation of a new concept and imagination that did not exist before [10].

In the open innovation model, organizations seek to acquire new information and technologies from outside the company [11]. The main issue is the reduction of the benefits companies obtain through internal resources, which forces them to use external knowledge sources of organizations [12]. In a very complex environment, open innovation is one of the main determining factors for the competitive advantage of economic enterprises [13], [14].

Open innovation describes the path of possible knowledge flow and the degree of participation in research and development of the organization. Even though knowledge is available and participation networks create value, effective knowledge management frameworks are necessary to increase knowledge absorption capacities. Open innovation provides a broad perspective of external knowledge for companies to turn their innovative products and services into profits [15]. Innovation is considered one of the primary sources of competitive advantage in the changing environment [16]. Organizations must develop adaptability and rapid innovation if they want to remain competitive. In the closed paradigm, companies develop innovations within and through their internal technologies and resources and then commercialize them [17].

2.2|Open Innovation Methods

Open innovation can be done through different methods, which are usually divided into the following two general categories:

The outside-in method

It enriches the company's knowledge base by integrating suppliers and customers and sourcing external knowledge. This process is called knowledge internalization. Accessing knowledge, technology, and information through communication with other companies facilitates open innovation and makes the company implement it efficiently [18]. A positive relationship exists between company performance and open innovation through effective competition with other companies; that is, the effective internalization of knowledge stimulates non-linear innovative ideas.

Inside-out method

It means making a profit by commercializing ideas and selling and upgrading technology by transferring ideas to the external environment. This process is called the externalization of knowledge. Environmental pressures can strongly affect company performance [19]. In general, the inside-out process and its results are the criteria for describing and evaluating the output of high-tech companies [20].

It should be noted that there are a large number of open innovation methods, which amount to 45 methods. But in *Table 1*, some common methods of open innovation are presented.

Table 1. Some common methods of open innovation.

Method		Definition	Researches
Out in (incoming)	Buy	Buying technology from foreign sources	Abulrub and Lee [21] Van der Meer [22]
	Obtaining a license	Obtaining a license to use the technology	Abulrub and Lee [21] Van der Meer [22] Fey and Birkinshaw [23]
	Mutual investment	Establishing a joint venture in cooperation with other companies to develop technology	Abulrub and Lee [21] Van der Meer [22] de Vrande et al. [24]
	Risky investment	Investing in promising technologies is a risky foreign sector with an uncertain future	Van der Meer [22] Fey and Birkinshaw [23]
	Outsourcing research and development	Buying research and development services from other organizations similar to research organizations	Van der Meer [22] de Vrande et al. [24] Kim et al. [25]
	Mergers and acquisitions	Acquiring companies or merging with technology companies in situations that solve internal technology development	Gassmann et al. [26]
	Customer involvement	Involving customers in the innovation process (market research to discover the need and develop products based on customer demand)	Abulrub and Lee [21] Kim et al. [25]
	External networking	Cooperation with foreign partners to acquire knowledge and technology	Chesbrough [4] Abulrub and Lee [21] Fey and Birkinshaw [23]
	Communication with scientific centers	Cooperation with scientific institutions such as universities	Chesbrough [4] Fey and Birkinshaw [23]
	Partnership with suppliers	Involving suppliers in the innovation process (product development using supplier technology)	Rangamiztousi and Ismail [27]
	Employee participation	Using the knowledge of internal employees who are not part of the research and development department of companies or organizations	de Vrande et al. [24]
	Competitors (participation in production)	A joint production of products or goods or services	Schotanus and Telgen [28]
	Scientific journals	Search in the latest scientific findings of universities, scientific institutes, and scientific institutions	Rangamiztousi and Ismail [27]
Inside out (outgoing)	Sale	Selling internal technology to the market for more profit	Abulrub and Lee [21]
	Granting permission	Licensing internal technology to external partners instead of direct commercialization	Chesbrough [4] Van der Meer [22] Fey and Birkinshaw [23] Kim et al. [25]
	Open source	Unveiling and introducing internal technology without regard for direct financial benefits in the short term	Brunswicker and Vanhaverbeke [29]
	Breeding companies	Creation of new companies based on internal technical knowledge and full support by the parent company	Chesbrough [4] Van der Meer [22] Fey and Birkinshaw [23]

2.3 | Research Background

Reviewing the studies and research done abroad and domestically shows the importance of research in the field of open innovation approach. For example, in 2006, the cost of research and development for the realization of innovation for Porsche automotive Company was 70 to 80 million euros, BMW, Volkswagen, and Daimler Benz up to 150 million euros due to the reduction of the product life cycle has always been this the industry seeks to reduce innovation costs [30]. Therefore, due to the importance of the topic, some of the studies conducted are mentioned below. It is pointed out that many researchers have chosen one or more innovative methods for their intended research and have emphasized them in their studies. However, in the current research, an attempt has been made to use a wider range of open innovation methods to make the research comprehensive.

Ili et al. [31] discussed providing a suitable model based on the current paradigm of the German automobile industry, and in this research, open innovation methods outside the organization, such as external communications, startups, consortia, consultants, research institutes, universities, communication with other industries, legislators, suppliers, competitors, and customers have pointed out that in the presented model, the customers and the next stage, the competitors have the most efficiency for innovation in the German automobile industry. Also, in this research, data from the Benz, BMW, and Volkswagen companies were used. Karlsson and Sköld [32] in their research regarding the use of effective open innovation methods in the acquisition of technology in the automotive industry in ways such as development requests, memorandums of understanding, reverse engineering, cross-licensing agreements, patent sales, alliances, and investments. The joint reimbursement licenses, consulting, research, and development alliances have been mentioned.

Ettabaa et al. [33] studied the model of the Toyota automobile company and examined the points of each method of open innovation for better car production; some of these methods include cooperation with common platforms, cooperation with startups, cooperation with research institutes, cooperation with consulting companies, design of topic-based competitions, open innovation laboratories, crowdsourcing through employees, social networks for design (for example, Renault company case study), design competitions, virtual car (design through the case study software of BMW Company), participation with government research institutions, employee participation, interaction with the web world, setting up a research and development unit, science fairs and technological intelligence institutes have been investigated in advancing the goals. The automobile industry, especially Toyota, has been evaluated as important.

Mazzola et al. [34] studied the model of open innovation methods in the automotive industry. They divided the most effective methods into two categories: outside-in and inside-out, which are suppliers. The university has proposed cooperation with government institutions, obtaining licenses and national resources for outside-in methods and licensing, outsourcing, foreign technology, commercialization, joint patenting, manufacturing, and R&D alliances for inside-out, which are in the industry. Automobile manufacturing has the greatest impact. Schroll and Mild [35], in their study of the automotive industry, address the diversity of input and output practices because open innovation can include several phenomena. In the meantime, the most effective in the automotive industry to obtain innovation have been summarized in 3 crowdsourcing methods: community-based innovation and mass customization.

Huizingh [36] has raised the impact of open innovation and the possibility of merging companies in the automotive industry due to the costs that the acquisition of new technology and car manufacturing brings to the company. Ramirez-Portilla et al. [37] based on the analytical model of annual reports from 2005 to 2012 of ten major car manufacturers, including Ford, Toyota, Renault, Daimler, Scania, Hyundai, DFM (Dongfeng), TADA, BMW, and Fiat, in this cross-sectional study, shows that open innovation is widely used among the world's leading car manufacturers, and in the meantime, in ways such as cross-licensing agreements, licensing, alliances, joint ventures, patents, sales, unit sales. It examines and describes commercialization, licensing, reimbursement, consulting, personnel exchange, development requests, reverse engineering, trend and technology research, learning trips, common laboratory research, online portals for ideas, marketplaces, competitions, and venture capital. These methods have good potential for use in the automotive industry.

In their study, Sudrajat et al. [38] propose the innovation method of strategic alliances. Strategic alliances are voluntary agreements between companies that share knowledge, resources, and capabilities to develop processes, products, or services. A strategic alliance is a comprehensive term that includes various forms of connection between organizations. It consists of alliances without equity or long-term contracts, alliances based on equity, and joint ventures. The most common types of alliances without equity are supply contracts, distribution contracts, and licensing contracts. Ahn et al. [39] investigated the relationship between open innovation and the performance of small and medium-sized companies. They found that networking, as one of the methods of open innovation and extensive and intensive interaction in cooperation with foreign partners, is positively related to the company's performance.

Technology and market-oriented open innovation (bilateral research and development, user participation, and open-source method) play a role in improving the performance of small and medium-sized companies, and companies with innovative performance can cooperate with non-competitive partners such as customers, consultants, intermediaries, and research institutions benefit [39]. In their research, Jacobfeuerborn [40] concluded that businesses that transfer their ideas to parties outside the organization by creating networks have higher productivity than businesses that do this. Do not give a two-way exchange of ideas instead of a one-way exchange, which increases the probability of the business benefiting greatly during new product development projects [30].

Lukač et al. [41] investigated the open innovation selection model in the information and communication technology industry, focusing on the flow of knowledge in companies active in this industry and analyzing the processes of inbound and outbound innovation. They identified the achievement of successful innovation to stay competitive in these companies only through collaborative methods. In their study, Mortara and Minshall [42] used the term measures to refer to open innovation. They presented a classification of open innovation approaches based on two criteria: organizational change resulting from the introduction of open innovation and the other method that coordinates actions. In their research, Bianchi et al. [43] referred to open innovation methods from outside to inside, such as purchasing scientific services and obtaining licenses, and open innovation from inside to outside, such as partnerships, offering scientific services, and licensing. Gassman et al. [26] concluded in their research that organizations that use open innovation methods from inside to outside are very interested in branding and standard development. They recommend choosing the open innovation method based on the companies' capabilities and position. In their study, Lazzarotti et al. [44] concluded that companies that choose the outside-in open innovation method to create new ideas and knowledge that can be integrated with the company's current knowledge decide to cooperate with universities and other public research organizations, suppliers, customers, competitors, etc.

Bianchi et al. [43] concluded in their research that the critical factor in the success of open innovation is the timely identification of the opportunity to provide the company's technology franchise outside its core business as one of the most widely used methods of open innovation and designed a quick and easy way to identify opportunities to provide technology franchises from inside the company to outside it. Diener and Piller [7] have shown that many innovative projects are based on external developments compared to similar projects based on internal research and development; they have shorter development times and require less investment. Therefore, he chooses to use this method to advance companies' projects.

Pilevari et al. [45] studied the management of an open innovation project portfolio to create integration at the project and company level with a study. Research findings in five categories, including strategic management of the open innovation project portfolio, culture management in the open innovation project portfolio, management of open innovation project portfolio processes, stakeholder management in the open innovation project portfolio and technology management in the open innovation project portfolio were divided. They also concluded that the field of culture management, the role of charismatic management, the field of process management, knowledge management, integrated market management, and the creation of processes for the organization's research and development unit had received less attention. In this regard, the current research provides a model for choosing the appropriate method of open innovation in the automotive industry using the ANFIS method. In the end, the summary of the above research regarding the correct selection of open innovation methods according to the characteristics and capabilities in different situations is shown in *Table 2*.

Table 2. Summary of the studies examined in the research.

Row	Ref.	Some of the most widely used open innovation methods, which have been emphasized in the research, are selected according to the conditions of the companies.													Description
		Mutual Investment	Open Source	Customer Participation	Involvement of Suppliers	Networking	Communication with Scientific Centers	Sale	The Copyright	Merge	Competitors	Employee Participation	Scientific Journals	Research and Development	
1	[38]	✓				✓									Choosing an open innovation method through sharing knowledge, resources, and capabilities to develop processes, products, or services
2	[39]		✓	✓		✓	✓						✓		Choosing an open innovation method to improve the performance of small and medium enterprises
3	[40]					✓									Choosing an open innovation method to increase productivity in companies
4	[46]				✓	✓	✓						✓		Choosing an open innovation method, emphasizing the acquisition of foreign knowledge and skills of companies
5	[41]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	We are choosing open innovation methods based on active companies based on exiting or entering practices, achieving successful innovation to stay competitive.

Table 2. Continued.

Row	Ref.	Some of the most widely used open innovation methods, which have been emphasized in the research, are selected according to the conditions of the companies.													Description
		Mutual Investment	Open Source	Customer Participation	Involvement of Suppliers	Networking	Communication with Scientific Centers	Sale	The Copyright	Merge	Competitors	Employee Participation	Scientific Journals	Research and Development	
6	[47]			✓	✓		✓		✓			✓	✓		Emphasis on the choice of open innovation method based on the needs of companies (exporting and importing)
7	[26]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Determining the method of open innovation based on the ability of companies
8	[44]			✓	✓		✓				✓	✓		✓	Emphasis on choosing and using outside-in innovation methods in companies
9	[43]								✓						Emphasis on the open innovation method based on the outside-in
10	[7]	✓												✓	Emphasis on the open innovation method based on external development

3 | Research Methodology

This research is applied in terms of purpose and descriptive survey in terms of the data collection method. Both library and field methods have collected the desired information. The tools for managing information in the library included books, articles, interviews, and questionnaires in the field section. The statistical population of the current research is 15 experts in the automotive and innovation industry who have at least 10 years of experience and have relevant articles and books in this field, who are in various specialties, including design, production, and sales of automobile marketing. The additional information about these people is shown in *Table 3*:

Table 3. Characteristics of people participating in the research.

Level of Education		Experience	Age of People		Gender of People			
					Man	Female	Activity	
P.H.D	26 %	10 to 25 years	25- 35	7%			Production	54%
Masters	34 %		35-45	54%	80 %	20 %	Designing	33%
Bachelor	40 %		45-55	39 %			sale	13%

In this research, input and output were selected in several steps. Because it is considered based on a case study to choose the open innovation method, the capabilities of each company are different because the technology available to each of them is also different. So, the inputs of the relevant model were based on interviews and experts' opinions. In the next stage of outputs, there are more than 45 open innovation methods (according to the reviews in the literature), but not all of these methods are suitable for the automotive industry. Therefore, among the available methods, nine were selected again during the expert interviews. After determining the input and output, it is time to determine the impact of each of them in the automotive industry, among which 200 parts out of about 5000 are selected by the experts with the most impact in car manufacturing (to avoid complexity).

The level of the company's ability to manufacture the part and the complexity of the technology required to manufacture the part in question has been determined. Based on this, the model's output also suggests a method for choosing open innovation according to the level of capability and technology available to the company. Therefore, all the indicators, dimensions, and components related to open innovation were identified and extracted through books, articles, theses, and generally, by reviewing the literature (according to *Table 2*). Then, to enrich it more, experts were interviewed in the field of automobile manufacturing, and after summarizing, the information was given to the expert community through a Delphi method questionnaire and, in the end, two main indicators as input, which were extracted from the interviews with the experts. Nine indicators extracted from the research literature and experts' opinions were determined as the model's output. It should be remembered that the number of open innovation methods is more than 45. According to experts' opinions in this research, the most widely used methods were mentioned in the previous sections. The input and output indicators of the model were selected as follows:

Input indicators

I. The level of technical knowledge of the company.

II. The complexity of the technology.

Output indicators

I. Participation of customers.

II. Participation of employees.

III. Participation of suppliers.

IV. Competitors.

V. Scientific journals.

VI. Communication with scientific centers.

VII. Research and development.

VIII. External networking.

IX. Investment.

Fig. 1 shows the inputs and outputs of the ANFIS model of the current research.

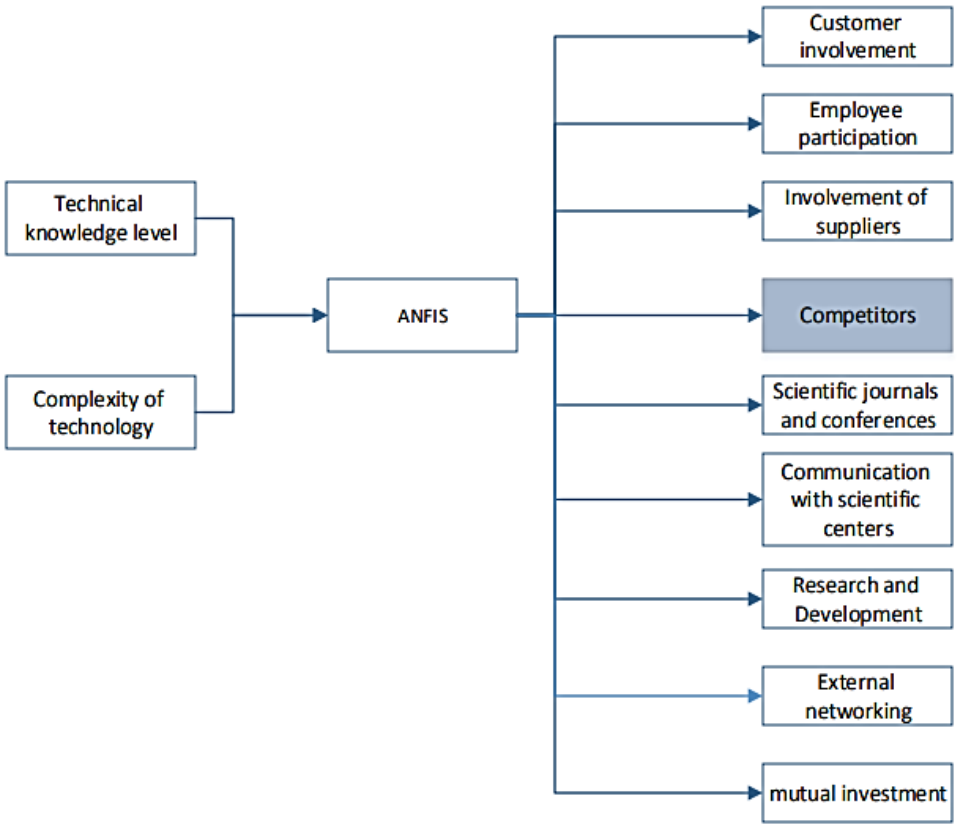

Fig. 1. ANFIS model inputs and outputs.

Therefore, according to the figure above, two inputs were determined for the proposed model to select one of the nine open lighting methods as the model's output using the ANFIS method and MATLAB software.

3.1|Network-Based Fuzzy Inference System

A fuzzy inference system based on the network is a type of artificial neural network based on the Takagi-Sugeno Fuzzy system. Jang [48] proposed this method for the first time in 1993. Since this system combines neural networks and vague logic concepts, it can use both possibilities in one frame. Its inference system is based on a set of fuzzy if-then rules that can learn to approximate non-linear functions.

Fig. 2 shows the general structure of the ANFIS model.

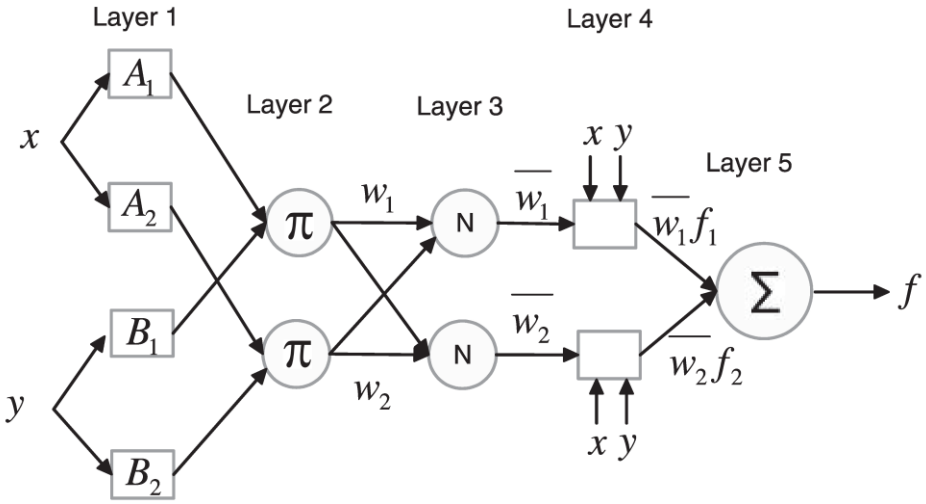

Fig. 2. The general structure of the ANFIS model.

First layer: In this layer, x or y input to node I and Ai or Bi-2 are the names of linguistic variables corresponding to this node.

Second layer: each node in this layer is a fixed node called P.

Whose output is the product of all input signals.

$$o_{3,i} = \bar{w} = \frac{w_i}{w_1 + w_2}, i = 1,2.$$

Third layer: In this layer, the only thing that takes place is to normalize the output of the second layer and transfer it to the next layer.

The fourth layer: each node I in this layer is a node corresponding to the function of the node, as follows:

$$o_{4,i} = \bar{w}_1 f_i = \bar{w}_1 (p_i + q_i y + r_i), i = 1,2,$$

where $\bar{w}_i$ is a normal excitation intensity of the third layer, and pi, qi, and ri are the set of parameters of this node. Also, the parameters of this layer are called inference parameters.

Fifth layer: the only node of this layer is a fixed node called Σ, which calculates all the outputs as a set of all the input signals as follows:

$$o_{5,i} = \bar{w}_1 f_i = \frac{\sum i w_i f_i}{\sum i w_i}, i = 1,2.$$

The reasons for using a ANFIS compared to other methods are as follows:

I. Maintains the benefits of a fuzzy expert system while reducing the need for an expert.

II. Using neural networks to sort data and identify patterns.

III. Due to the use of fuzzy logic, the problems of modeling and analyzing complex data are reduced in this method.

IV. It can learn while maintaining the advantages of the fuzzy inference system.

V. It is possible to enter qualitative human experiences.

VI. Creating a transparent fuzzy inference system that has few errors and shows fewer errors in calculations than the neural network [49].

3.2 | Conceptual Model of Research

In this research, the network is trained and designed based on two input and one output parameter. The input parameters include the level of technical knowledge of the company and the complexity of the technology of the parts, and the output parameters include open innovation methods, including customer participation, employee participation, supplier participation, competitors, scientific journals, communication with scientific centers, research, and development, external networking, and capital are shared. It should also be noted that the mentioned model is trained for a set of products and one output; for example, competitors are the result. Still, for another set, according to the data, it can give us another output, such as the participation of suppliers. Considering that a car consists of about 5000 parts. Therefore, to reduce the cost and waste of time, based on experts' opinions, some of the important and strategic parts in the car were examined and studied, among which 200 main parts were selected, and the model was trained based on the data assigned to these parts. Also, 50% of the data for training and 50% for testing the model were determined. It is necessary to remember that this data has been determined by experts in the input and output determination section (data matrix), and values have been assigned to each of the parts to choose the appropriate method with the lowest amount based on the existing conditions of a company (case study). Make an error. So, the model is trained only by changing the values in the input; the output also changes accordingly. As stated in the previous parts of the research, these variables were selected from various factors, considering the presence of a questionnaire for experts in the automotive industry. *Fig. 3* schematically shows the process of determining the open innovation method:

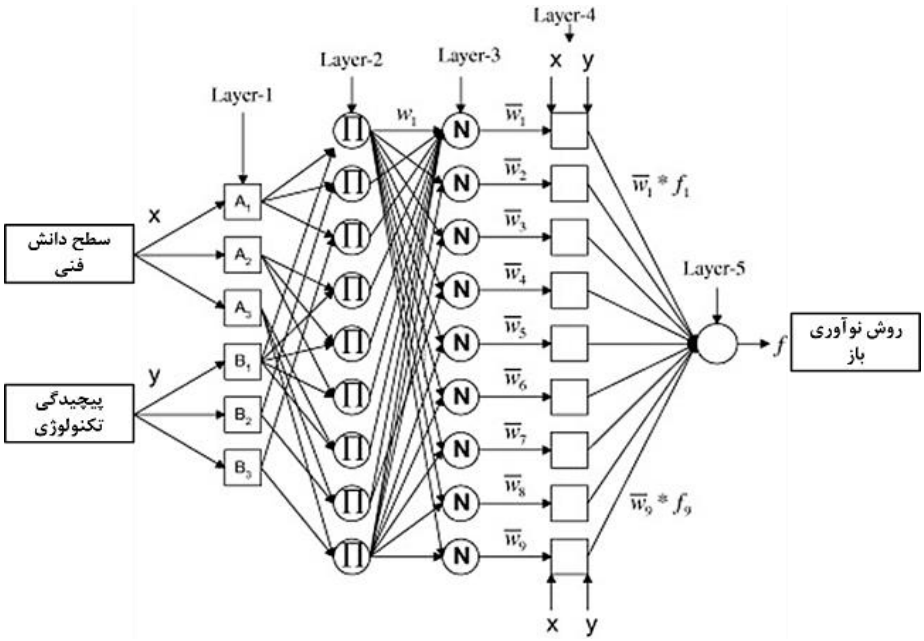

Fig. 3. The process of choosing the open innovation method of the proposed model.

3.3 | Validation

Validation of the present research has been considered from two points of view. First, the validity of the questionnaire was confirmed by experts. Then, the validation of the model is determined based on the difference between the outputs of the model and the real data. The data used in the validation must be random and not used in the model training process so that the model can be tested using this data. Usually, in the validation of an ANFIS, the parameters of Root Mean Square Error (RMSE), relative error percentage (ε), Mean Absolute Error (MAE), and explanation coefficient (R^2) are used for validation [50]. *Table 4* shows the model validation results.

Table 4. Validity of ANFIS model.

Validation Criteria	Optimal Values	Model Values
Coefficient of explanation (R^2)	Between 0.6 and 0.8 is good, and between 0.8 and 1 is excellent.	0.932
Relative error percentage (ε)	The less, the bette.	0.0112
RMSE	The less, the bette.	0.19
MAE	Comparing the two systems, the less is the more suitable.	0.029

The above results show the high accuracy and reliability of the proposed model when choosing the open innovation method.

4 | Findings and Analysis

In this research, the information related to achieving various open innovation methods selected by experts was first obtained and stored in a table. This table specifies the chosen method for open innovation for each level of technical knowledge and technology complexity. Then, the stored data were entered into MATLAB software. In the next step, the ANFIS model was created and trained by coding in MATLAB. It should be noted that in this research, the data were applied to the ANFIS in two modes: training and testing. As mentioned in the previous section, the information related to the car's components was determined for training the model, which is related to 200 parts selected by the experts. Therefore, a table contains the input values that result from the company's ability to develop the technology of manufacturing parts and the amount of technology required for manufacturing parts. Experts specified all the values, and based on the available data, the model was implemented for training and error reduction. In this way, 100 data (related to 100 parts) out of 200 data (50% of data) were randomly extracted using a suitable function in MATLAB, and the ANFIS model was trained using them. It should also be added that input information should be considered for car parts to avoid data overload. *Fig. 4* shows how to create and train the ANFIS model using the reduction clustering method.

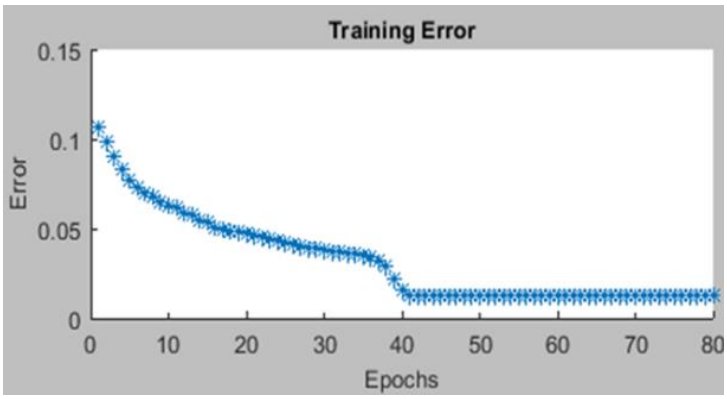

Fig. 4. Training error in the ANFIS model created using the deductive clustering method.

As one can see, the number of training errors in the figure is 0.012. Also, the most suitable course for selecting and completing the training stages of the model using the clustering (categorization) reduction method is 40. In addition, the value of the membership functions for the inputs is automatically considered 24, and the hybrid method is used as the optimal method for training.

Then, the trained model was tested for evaluation. For this purpose, 100 out of 200 data (50%) have been considered for testing the designed ANFIS model. *Fig. 5* shows the error of the test data in the created ANFIS model.

Fig. 5. Error diagram of test data created in ANFIS model.

As can be seen, the error rate of the test data is 0.19, which is an acceptable level. This shows the high compatibility of the model's features with the collected data, and it indicates that the designed ANFIS model can establish high accuracy in identifying the appropriate open innovation method.

In summary, the following actions have been taken:

I. Selection of inputs, including the company's ability and technology complexity.

II. Determining the input values based on the construction of the part in a question and based on the car manufacturing company.

III. Determining the values of 200 pieces based on two input variables by experts.

IV. Determining the appropriate function for the model.

V. Selection of 100 data from relevant parts to train the model, run it, and extract the resulting outputs.

VI. Selecting 100 pieces of data to test the model, run it, and extract the resulting outputs.

VII. Final evaluation and validation of the model.

5 | Conclusion

Today, the increase in the speed of technological changes to increase productivity and reduce costs in car production by car manufacturing factories and the growing number of trips has led to an increase in competition to provide the right car with quality and competitive commercial price. Innovation is not a one-time phenomenon but a continuous process consisting of the organizational decision-making process at all stages, from developing a new idea to its implementation. Today, innovation is defined as an interactive process for problem-solving and learning. Therefore, we must find new technologies to remain competitive globally. The current research aimed to select the appropriate open innovation method for the automotive industry using an ANFIS. For this purpose, based on the opinion of experts, two inputs and one output out of 9 possible modes were taken into consideration. In other words, the input values of the output model, which are the same as those of the open innovation method, also change. The input parameters include the level of technical knowledge of the company and the complexity of the technology of the parts, and the output parameters include open innovation methods, including customer participation, employee participation, supplier participation, competitors, scientific journals, communication with scientific centers, research, and development, external networking, and capital are shared. In the next step, the ANFIS model was created and trained by coding in MATLAB. The ANFIS model was trained with 50% of the data using the deductive clustering (classification) method. Then, the created model was tested on experimental data (50%). The results showed that the designed model chose the open innovation method with 90% accuracy. Therefore, it can be concluded that ANFIS is a suitable tool for choosing the open innovation method for the automotive industry. Also, the result of the model validation showed that all the parameters intended for

validation are in the optimal range, which shows the high fit of the model inputs with the collected data and indicates that the designed ANFIS model can accurately be open in choosing innovative methods. Much research has been done on open innovation. Also, the study of Diener and Piller [7], Jacob et al. [40], and Sudrajat et al. [38] with the current research in terms of open innovation methods studied include networking, communication with customers, suppliers, employees, etc. are in harmony in the current research, it should be noted that the results obtained are based on the opinions of experts from one of the automobile companies. According to the results, the data will differ based on the input information of the manufactured product and the manufacturing company. In the end, considering the high accuracy of the ANFIS model in predicting the open innovation method and its effect on the technological progress and development of the automobile industry, it is recommended that the managers and officials of the automobile industry in their planning and decision-making Use this model. It is also suggested that researchers in future research investigate the following issues:

I. Using other innovation methods that are not discussed in this research.

II. Using other methods other than ANFIS to choose an open innovation method such as genetic algorithm or neural networks.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

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